BG Pulse Journal USA
ISSN:1947-2536 http://www.bgpulseusa.com/index.php/bg
BG PULSE JOURNAL

# MASSIVE LANDSLIDE AT THE BINGHAM CANYON COPPER MINE: GEOPHYSICAL OBSERVATIONS AND ANALYSIS

**F. R. Usmonov**
Asia International University
Lecturer of the "General Technical Sciences" Department

**Annotation:** On April 10, 2013, a major slope failure occurred at the Bingham Canyon copper mine in Utah, United States. The collapse affected the northeastern wall of the open-pit mine and took place in two separate episodes. Each failure lasted approximately one and a half minutes, with an interval of about ninety minutes between them. The total volume of displaced material reached nearly 65 million cubic meters, making it one of the largest non-volcanic landslides ever documented in North America.

No casualties were reported because mining personnel had identified warning signs of instability in advance and evacuated the affected zone before the collapse occurred. The event was exceptionally well recorded due to the presence of numerous seismic and infrasound monitoring stations surrounding the mine.

Analysis of the seismic records revealed both short-period and long-period signals that were detected across a wide regional network. Magnitude estimates based on conventional local seismic methods were relatively modest, whereas calculations derived from signal duration indicated considerably larger values. This contrast is characteristic of large landslide-generated seismic events. Furthermore, several small earthquakes were recorded in the vicinity of the mine during the days following the collapse. Their seismic signatures resembled tectonic earthquakes, suggesting that the landslide itself may have triggered local seismic activity rather than being triggered by an earthquake.

**Keywords:** Bingham Canyon Mine, landslide, rock avalanche, seismic signals, infrasound monitoring, slope stability, geotechnical monitoring, induced seismicity, open-pit mining, hazard mitigation.

## Introduction

Landslides represent one of the most significant natural geological hazards worldwide. Every year they cause substantial economic losses, damage infrastructure, and result in thousands of fatalities. During recent decades, numerous catastrophic slope failures have demonstrated the destructive potential of large-scale mass movements, particularly in mountainous and mining regions.

Despite their hazardous nature, advances in monitoring technologies have significantly improved the ability to identify unstable slopes before catastrophic failure occurs. Modern geotechnical monitoring systems provide valuable information regarding ground deformation, allowing engineers and geologists to assess risks and implement preventive measures.

The Bingham Canyon landslide of April 2013 provides a remarkable example of successful hazard prediction and risk mitigation. Because the instability was detected before failure, the mine operators evacuated personnel and equipment from the endangered area, preventing loss of life. In

addition, the landslide occurred within a region equipped with a dense network of seismic and acoustic monitoring instruments. Consequently, the event generated an extensive dataset that has become highly valuable for understanding landslide dynamics and associated geophysical processes.

**The Bingham Canyon Landslide:** The Bingham Canyon open-pit copper mine is situated in the Oquirrh Mountains approximately 33 kilometers southwest of Salt Lake City, Utah. On April 10, 2013, a massive rock avalanche originated from the northeastern wall of the mine, producing a large scar on the slope and depositing enormous quantities of debris across the pit floor.

The geometry and travel characteristics of the displaced material indicate that the event can be classified as a rock avalanche, a type of rapid mass movement involving large volumes of fragmented rock traveling at high velocity over considerable distances. The extensive runout observed within the mine confirms the highly mobile nature of the failure.

The Bingham Canyon mine is recognized as one of the largest human-made excavations in the world, exceeding 970 meters in depth. Since beginning operations in 1906, it has played a major role in copper production within the United States. Due to the enormous scale of the excavation, slope stability has long been a critical operational concern.

To manage this risk, mine operators implemented an advanced monitoring program that included automated surveying systems, extensometers, and radar-based deformation measurements. These technologies detected progressive movement within the northeastern wall months before the collapse occurred.

Throughout early 2013, monitoring data revealed accelerating ground displacement in the unstable area. As a precautionary measure, facilities located near the potential failure zone were removed, and access restrictions were imposed. On the day of the collapse, movement rates increased dramatically, leading mine officials to conclude that failure was imminent. Personnel and equipment were evacuated several hours before the first major collapse occurred.

The initial rock avalanche took place during the evening of April 10, followed by a second failure approximately ninety minutes later. Although no injuries occurred, substantial damage affected mine infrastructure. Several haul trucks, loading shovels, and transportation routes were either damaged or rendered unusable.

Estimates derived from digital terrain models indicate that approximately 165 million tons of rock were displaced during the event. The source volume was calculated at roughly 55 million cubic meters, while expansion during fragmentation increased the final deposit volume to nearly 65 million cubic meters.

When compared with other major landslides in North America, the Bingham Canyon event ranks among the largest ever documented. The scale of the failure exceeded that of several historically significant rock avalanches and demonstrated the enormous destructive potential associated with large-scale slope instability in mining environments.

BG Pulse Journal USA
ISSN:1947-2536 http://www.bgpulseusa.com/index.php/bg
BG PULSE JOURNAL

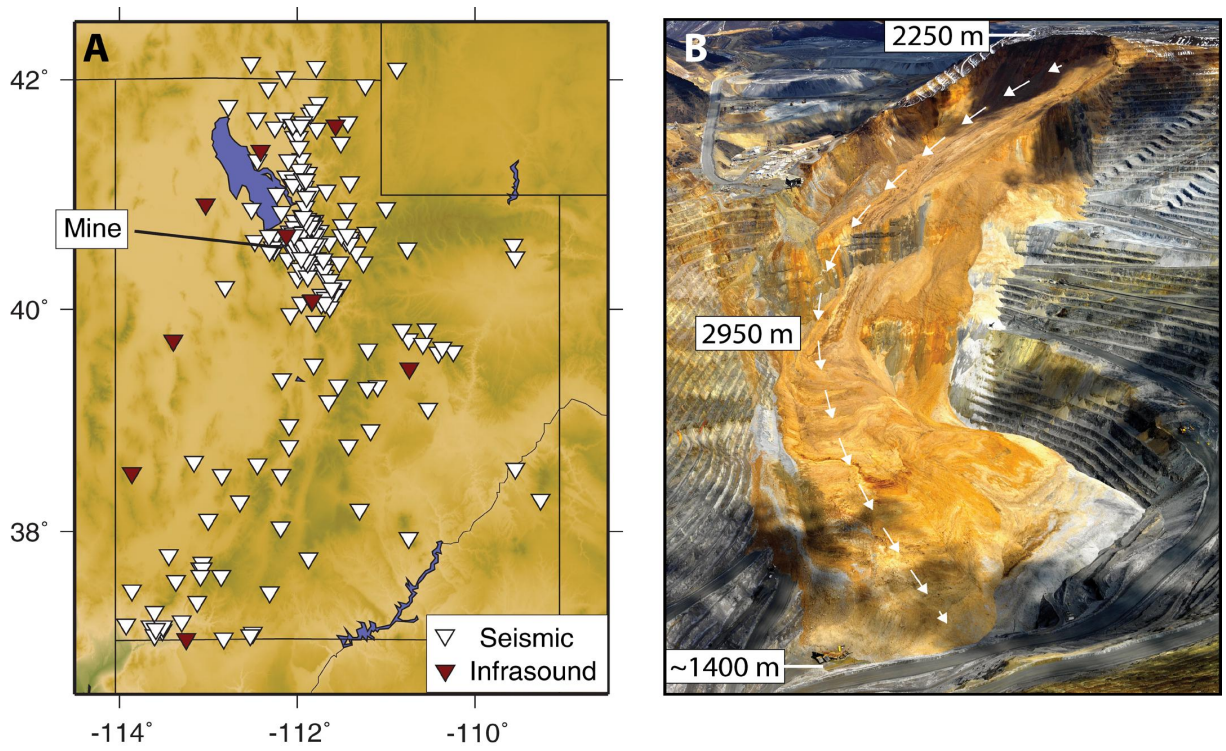



**Figure 1. (A) University of Utah seismic and infrasound network, and location of the Bingham Canyon mine. (B) Photograph of the 10 April 2013 rock avalanche (copyright Kennecott Utah Copper, used with permission). Elevation of the crest and toe of the slide are shown, as well as an estimate of the runout distance along the arcuate travel path. A group of large haul trucks damaged by the slide can be seen at lower left.**

The 1965 Hope rock slide in British Columbia (47 million m3), the 1959 Madison River Canyon landslide in Montana (30 million m3), and the 1903 Frank slide in the Northwest Territories of Canada (30 million m3). In North America and worldwide, rock avalanches of this size routinely claim lives; the Madison River Canyon slide killed 28, the Frank slide killed up to 90, while the 2009 Xiaolin landslide in Taiwan (25 million m3) caused nearly 500 fatalities. These statistics highlight the potentially devastating consequences of catastrophic rock avalanches and emphasize the importance of early-warning monitoring systems, such as those used at the Bingham Canyon mine.

Rock avalanches are distinguished from other types of landslides by their massive volume and characteristically fast and long runout. While rock fall debris, for example, accumulates at steep inclinations close to the angle of repose, rock avalanche deposits can spread over many kilometers, leaving gently inclined, characteristically hummocky terrain containing highly crushed and fragmented, yet compact, debris. Typical flow velocities are in the range of tens of meters per second and can reach as high as 100 m/s (e.g., Crosta et al., 2004). In the past, such runout was often thought to be anomalous, but today we know it is common for source volumes of this size that fail in a catastrophic manner, although the precise mechanisms driving rock avalanche dynamics are still debated (Davies and McSaveney, 2012). Comparing the geometry (fall height and length) of the Bingham Canyon rock avalanche with other events from across the globe shows that, at roughly 2950 m, the total travel distance from crest to toe is within the expected range for events of this size (Fig. 2). The slide would likely have run farther had it not impacted the southern

pit wall. Considerable variability exists within the global data set, however, and precise prediction of runout distance, even with the aid of numerical modeling, is challenging.

Local news agencies reported initial cost estimates related to the Bingham Canyon rock avalanche approaching one billion dollars. If these estimates prove correct, the rock avalanche will become the most expensive landslide in U.S. history, surpassing the 1983 Thistle slide (also in Utah), which at the time was estimated to have cost between 460 and 940 million dollars (values adjusted for inflation). For now, the successful monitoring and hazard mitigation are heralded as an achievement, as well as an example to others facing the danger of catastrophic rock slope failures.

**Seismic and Infrasound recordings of the Landslide:** The University of Utah Seismograph Stations (UUSS) has operated a seismic network in the Utah region (Fig. 1A) since the early 1960s (Pechmann et al., 2007; Thomas et al., 2013) with the goal of detecting, locating, and characterizing regional earthquakes associated with the Intermountain Seismic Belt (Smith and Arabasz, 1991). The network is a Tier I component of the Advanced National Seismic System (ANSS) of the U.S. Geological Survey (USGS, 1999) and is funded via a state-federal partnership. As of 1 April 2013, the Utah network consisted of 200 seismographs, including broadband, accelerometer, and short-period sensors, generating 667 channels of 100 Hz seismic data, which are telemetered in near–real-time to the UUSS operations center and archived at the public data center of the Incorporated Research Institutions for Seismology (IRIS, see www.iris.edu). Station density is greater along the Wasatch Front, an area of high seismic hazard. In addition to the seismic network, UUSS operates nine infrasound arrays throughout the state in collaboration with Southern Methodist University and Los Alamos National Laboratory (Hale et al., 2010).

Seismic signals from the Bingham Canyon landslide were recorded by UUSS at distances ranging from ~6 to over 400 km, while infrasound signals were recorded at seven arrays at distances from 13 to 400 km. Inspection of the seismic data importantly revealed that the landslide consisted of two distinct rock avalanche events separated by ~1.5 h. Raw seismograms for the two rock avalanches appear similar and are dominated by persistent, long-period (>10 s) energy; however, isolation of the long-period signals reveals significant differences (Fig. 3). For example, low-passed data from the first rock avalanche show a high-amplitude peak near the end of the coda, a feature that the second event lacks; meanwhile, the timing of the two maxima differs by tens of seconds.

Inspection of the infrasound data confirms that there were two distinct rock avalanche events. Figure 3 shows beams formed by steering the arrays at two stations, NOQ and WMUT, toward the mine. For the first rock avalanche, there is a coherent signal on both arrays, arriving at times consistent with the slide as the source. However, at NOQ (13 km from the mine) the energy consists primarily of a sharp impulse, while at WMUT (57 km from the mine) the energy is >30 s in duration with both a long onset and coda. Differences in the waveforms likely result from different atmospheric travel paths. For the second rock avalanche, array processing shows no coherent signal at NOQ coming from the mine, while the coherent signal at WMUT is short in duration and only slightly visible above background noise. Infrasound data from the second event are more difficult to discern because of increased background noise, possibly due to local winds (there was a rainstorm the night of the landslide).

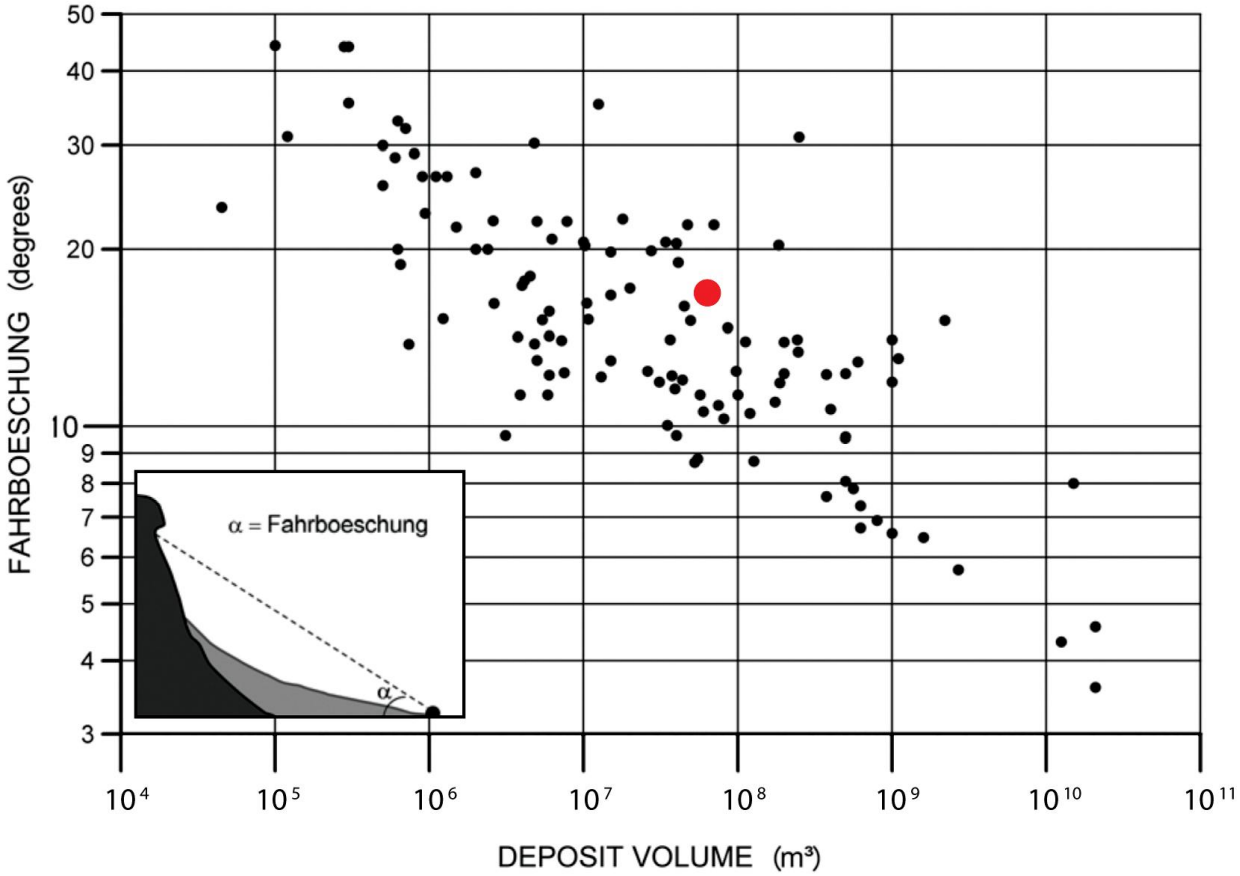



**Figure 2. Comparison of the Bingham Canyon rock avalanche (red dot) with other reported landslide events from across the globe (figure modified from Bourrier et al., 2013, with data from C. Davidson, unpublished M.Eng. thesis, 2011). The estimated geometry results in a Fahrboeschung value (defined as the angle a relating the fall height and length) of 16°, which is within the expected range for events of this size.**

We can use the seismic observations to generate first-order estimates of the relative volumes of the two rock avalanches. Comparing signal durations, peak amplitudes of the seismogram envelopes, and area underneath each envelope (as in Dammeier et al., 2011), we find that the two slides were roughly equal in volume; this would correspondingly split and move the data point presented in Figure 2. We note, however, that photographs suggest that the second rock avalanche likely contained a greater proportion of waste-rock deposited on the slope during previous mining and so may have had a lower bulk density than the first failure. Photographs also show that the first rock avalanche filled the entire pit f loor, while the second apparently stopped short of the southern wall, suggesting the first slide may have been slightly larger.

The ultra-emergent nature of seismic signals from the rock avalanches made standard earthquake detection algorithms employed by UUSS ineffective. Such power detectors rely on short-term versus long-term averages and are tuned to alarm on impulsive P waves. However, the two rock avalanches were automatically detected and located using an algorithm based on the continuous back propagation of globally recorded long-period surface waves (Ekström, 2006), which has previously been successful in detecting large landslides (Ekström and Stark, 2013). The

detection amplitudes correspond to surface-wave magnitudes (Ms) of 5.1 and 4.9 for the first and second events, respectively (G. Ekström, personal commun., 2013).

**Conclusion:** The 2013 Bingham Canyon landslide represents one of the largest non-volcanic mass movement events ever recorded in North America. Owing to advanced geotechnical monitoring systems and effective risk management practices, the instability was identified before catastrophic failure occurred, preventing casualties and minimizing human losses. The event provided a unique opportunity for scientists to investigate the dynamics of large-scale rock avalanches using extensive seismic and infrasound datasets.

The analysis demonstrated that the landslide consisted of two major collapse episodes and generated complex seismic signals distinguishable from ordinary tectonic earthquakes. Furthermore, several small earthquakes detected after the failure suggest a possible relationship between large-scale slope collapse and induced seismic activity. These findings contribute significantly to the understanding of landslide mechanics, hazard assessment, and monitoring strategies in large open-pit mining operations. The Bingham Canyon event remains an important case study for improving early-warning systems and reducing risks associated with catastrophic slope failures.

## References

1. Bourrier, F., Dorren, L., and Hungr, O., 2013, The use of ballistic trajectory and granular flow models in predicting rockfall propagation: Earth Surface Processes and Landforms, v. 38, p. 435–440, doi: 10.1002/esp.3372.
2. Crosta, G.B., Chen, H., and Lee, C.F., 2004, Replay of the 1987 Val Pola landslide, Italian Alps: Geomorphology, v. 60, p. 127–146, doi: 10.1016/j.geomorph .2003.07.015.
3. Dammeier, F., Moore, J.R., Haslinger, F., and Loew, S., 2011, Characterization of alpine rockslides using statistical analysis of seismic signals: Journal of Geophysical Research, v. 116, F04024, doi: 10.1029/2011JF002037.
4. Davidson, C., 2011, Rock avalanches [unpublished M.Eng. thesis]: Vancouver, University of British Columbia, 13 p.
5. Davies, T., and McSaveney, M., 2012, Mobility of long-runout rock avalanches, *in* Clague, J.J., and Stead, D., eds., Landslides: Types, Mechanisms and Modeling: New York, Cambridge University Press, p. 50–58.